GUIDELINES
FOR THE P-3 UNSTABLE SLOPE INVENTORY AND PRIORITIZATION PROCESS

To inventory and prioritize unstable slopes for the P-3 Unstable Slope Program requires involvement of many partners in a multi-step process. Those partners include Regional Maintenance, Regional Materials Engineers, Regional Program Managers, OSC Office of Program Management, and the FOSSC Geotechnical Branch. The specific responsibilities of each partner are as follows:

✓ **Regional Maintenance Superintendents:** Identification of known unstable slopes. (See Step No. 1)

✓ **Regional Materials Engineers:** Numerically rate each known unstable slope within their Region. (See Step No. 2 for description of the eleven rating categories used to rate unstable slopes.)

✓ **FOSSC Geotechnical Branch:** Manages the unstable slope management system (USMS) that is part of the P-3 Preservation Program. Conducts field reviews of unstable slopes. Develops conceptual designs, performs cost-benefit analyses, and generates prioritized lists of unstable slopes statewide for programming purposes.

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✓ **Regional Program Managers:** Develop Project Definition cost estimates using the information contained in the conceptual designs developed by the Geotechnical Branch. Other required project costs such as mobilization, traffic control, surfacing and paving, preliminary engineering, construction engineering are considered.

✓ **OSC Office of Program Management:** Manages the P-3 Preservation Unstable Slope Program identified with the Washington's Transportation Plan element titled the Highway System Plan. Works with Executive Management in taking statewide deficiencies in all action strategies and making decisions on where to commit funds based on available revenues.

The following **STEPS** identify the sequence and type of information that is required for the P-3 unstable slope inventory and prioritization process:

Step No. 1: This step requires that the Maintenance Superintendents within each region develop a detailed and accurate list of known unstable slopes. This step was largely completed during the initial development of the Unstable Slope Management System. As new unstable slopes develop or existing unstable slopes worsen the Regional Materials Engineer should be supplied with updated information concerning those unstable slopes.

The important information that is required is as follows:

- State Route (SR) Number

- The beginning and ending mileposts for **each** unstable area. It is very important that the milepost limits be as accurate as possible. Also determine whether the unstable area is left, right (or both) of centerline in the **increasing** milepost direction.

- Make a preliminary determination of the cause of instability. For the purposes of this initial determination we prefer to limit the choices to the following categories of problem types, defined as follows:

    * **Slope Erosion** - The wearing away of a soil mass by the actions of running water. On slopes this process can result in the overland flow of water in an unconcentrated sheet wash, or the development of rills (e.g., small soil grooves or channels). Along streams or rivers the process can entail the near vertical undercutting of the adjacent stream/river banks.

    * **Settlement** - The vertical displacement of a soil mass **not** associated with a horizontal movement within a slope or embankment. Generally movement is slow. **Piping** occurs when erosion of subsurface soil, associated with groundwater flow, causes failure of the soil.

    * **Landslide** - The vertical and horizontal displacement of a soil mass, under the influence of gravity, within a slope or embankment. Generally landslides can be divided into two categories based on failure geometry. Those landslide categories are circular and sliding block failures. The rate of movement of landslides can vary from very slow moving to very rapid.

    * **Debris Flow** - A rapidly moving fluid mass of rock fragments, soil, water, and organic material with more than half of the particles being larger than sand size. Generally debris flows occur on steep slopes or in gullies and can travel long distances. Typically, debris flows result from unusually high intensity rainfall, or rain on snow events.

    * **Rockfall** - The fall of newly detached segments of bedrock of any size from a cliff or steep slope. The rockfall descends mostly through the air by free fall, bounding, or rolling. Movements are very rapid to extremely rapid, and may not be preceded by minor movements.

- Estimate the failure frequency for each unstable area. This category is based on the following criteria:

    * Failure occurs at a frequency greater than once in five years.
    * Failure occurs at a frequency of once in five years.
    * Failure occurs at a frequency of once a year.
    * Failure occurs at a frequency of more than once a year.

- Determine the annual maintenance costs that are incurred at each unstable area. These maintenance costs do not have to be exact, but should reflect reasonable estimates based on the knowledge of the Maintenance Superintendents. These maintenance costs include such items as ditch maintenance, roadway debris cleanup, roadway repair and patching, drainage, etc. that are associated with an area of instability. If these cost estimates cannot be obtained, then we would recommend that the costs be bracketed based on the following ranges:

    * Less than $5,000 per year
    * $5,000 to $10,000 per year
    * $10,000 to $50,000 per year
    * Greater than $50,000 per year

This information should be transmitted to the Regional Materials Engineer so that Step No. 2 of the process can be completed.

Step No. 2: WSDOT uses a numerical system to rate unstable slopes. The numerical rating system is a matrix evaluation system, which objectively evaluates the potential hazard of an existing unstable slope. Within each of the eleven rating categories are four columns that correspond to logical breaks in the rating categories, with exponentially increasing point values from left to right. The point values for each rating category increase from 3 to 81 to distinguish increasing importance or hazard potential. The total points for this rating system range from a low of 33 to a high of 891. Unstable slopes with a higher number will generally represent a greater risk. **It is important to note that the numerical rating system does not predict which slope will fail first, only its' relative hazard based on the risk factors that are evaluated.**

Before an unstable slope rater can determine how to score an unstable slope using the numerical rating system, the criteria for each rating category must be thoroughly understood. Some of rating categories will require a subjective evaluation, while others can be measured directly and then scored. The following Table 1 identifies the unstable slope numerical rating system categories and the rating criteria for each of the categories.

Table 1: **Unstable Slope Numerical Rating System**

RATING CRITERIA				
CATEGORY	Points = **3**	Points = **9**	Points = **27**	Points = **81**
Problem Type: **SOIL**	Cut or Fill Slope Erosion	Settlement or Piping	Slow Moving Landslide	Rapid Landslide or Debris Flow
Problem Type: **ROCK**	Minor Rockfall Good Catchment	Moderate Rockfall Fair Catchment	Major Rockfall Limited Catchment	Major Rockfall No Catchment
Average Daily Traffic	<5,000	5,000 - 20,000	20,000 - 40,000	>40,000
Decision Sight Distance	Adequate	Moderate	Limited	Very Limited
Impact of Failure on Roadway	<50 Feet	50 - 200 Feet	200 - 500 Feet	>500 Feet
Roadway Impedance	Shoulder Only	1/2 Roadway	3/4 Roadway	Full Roadway
Average Vehicle Risk	<25% of the Time	25% to 50% of the Time	50% to 75% of the Time	>75 % of the Time
Pavement Damage	Minor - Not Noticeable	Moderate - Driver Must Slow	Severe - Driver Must Stop	Extreme - Not Traversable
Failure Frequency	No Failures in Last 5 Years	One Failure in Last 5 Years	One Failure Each Year	More Than One Failure Per Year
Annual Maintenance Costs	< $5000 Per Year	$5000 to $10000 Per Year	$10000 to $50000 Per Year	>$50000 Per Year
Economic Factor	No Detour Required	Short Detour < 3 Miles	Long Detour > 3 Miles	Sole Access No Detour
Accidents in Last 10 Years	1	2 to 3	4 to 5	>5

The following is a description of each of the eleven rating categories of the unstable slope rating system:

Rating Category No. 1: Problem Type

***Problem Type*: SOIL**	**Cut or Fill Slope Erosion**	**Settlement or Piping**	**Slow Moving Landslide**	**Rapid Landslide or Debris Flow**
***Problem Type*: ROCK**	**Minor Rockfall Good Catchment**	**Moderate Rockfall Fair Catchment**	**Major Rockfall Limited Catchment**	**Major Rockfall No Catchment**

The nature of unstable slope conditions is evaluated in this category. Since most slope instabilities can be classified into two general types (i.e., unstable slopes involving primarily soils, and unstable slopes that are predominately rockfall related), we have developed rating criteria for both. **When rating an unstable slope only one of the problem types should be used.** In the event that both problem types are present at the site, the worst-case problem type should be rated.

- ***Problem Type*: SOIL** - These unstable slope conditions deal exclusively with soil or soil like instabilities. The categories are based on the definitions found in Step No. 1 (i.e., slope erosion, settlement, landslide, and debris flow), and are rated based on the potential speed of failure. Although the rates are somewhat subjective, we would offer a guide to the two end conditions. Slow would be defined as a progressive ongoing movement of small magnitude over a period of years. Rapid would be defined as sudden movement of large magnitude over a very short period of time, generally less than a day.

- ***Problem Type*: ROCK** - These unstable slope conditions deal exclusively with rockfall, based on the definition found in Step No. 1. The category evaluates the amount of rockfall catchment that is presently available to contain and prevent the rockfall from entering the roadway. The rockfall ditch criteria in the WSDOT Design Manual (Figure 640-4a) can be used as a guideline for evaluating effective rockfall catchment criteria. This category also subjectively evaluates the size of the events in terms of minor, moderate, and major rockfall. For purposes of consistency the following definitions should apply:

Minor Rockfall - Rockfall that is less than one foot in diameter and less that three cubic yards in volume.

Moderate Rockfall - Rockfall that is between one to two feet in diameter, and three to six cubic yards in volume.

Major Rockfall - Rockfall that is greater than two feet in diameter, and greater than six cubic yards in volume.

Rating Category No 2: Average Daily Traffic

Average Daily Traffic	< 5000	5000 to 20000	20000 to 40000	> 40000

This category rates the current Average Daily Traffic along the section of highway where the unstable slope is located.

Rating Category No. 3: Decision Sight Distance

Decision Sight Distance	Adequate Sight Distance	Moderate Sight Distance	Limited Sight Distance	Very Limited Sight Distance

The decision sight distance is a measure of the minimum distance (in feet) required for a driver to detect a hazard, make an instantaneous decision, and take a corrective action. For the purposes of the unstable slope inventory the Decision Sight Distance criteria found in AASHTO "Policy on Geometric Design of Highways and Streets," Table III-3 (McGee, H. W. *et al*, 1978) has been simplified. The Decision Sight Distance criteria in Table 2 represent the minimum values from AASHTO Table III-3. The posted speed limit is used.

Posted Speed Limit (mph)	Decision Sight Distance (ft)
30	450
40	600
50	750
60	1000
70	1100

Table 2: **Decision Sight Distance**

The actual sight distance at the unstable slope site is defined as the measured horizontal distance at which a six-inch high object disappears when the eye height is at 3.5 feet. This distance needs to be measured when the detailed rating is being conducted at the unstable slope. Both the horizontal and vertical sight distance should be evaluated.

The criteria in the Decision Sight Distance category are based on a ratio (expressed as a percentage) of the Actual Sight Distance and the Decision Sight Distance. This ratio is called the Percent of the Decision Sight Distance (**PDSD**). To determine the **PDSD** the following formula is used:

$$PDSD = \frac{\text{Actual Sight Distance}}{\text{Decision Sight Distance}} \times 100\%$$

The four rating criteria for the Decision Sight Distance category are defined as follows:

- **Adequate Sight Distance** - The **PDSD** is 100% or greater.
- **Moderate Sight Distance** - The **PDSD** ranges between 80% and 99%.
- **Limited Sight Distance** - The **PDSD** ranges between 60% and 79%.
- **Very Limited Sight Distance** - The **PDSD** is less than 60%.

Rating Category No. 4: Impact of Failure on Roadway

Impact of Failure on Roadway	< 50 Feet	50 to 200 Feet	200 to 500 Feet	> 500 Feet

This category measures the actual failure length (as measured in the field) of the unstable area along the roadway. This length is also used in the calculation of the Average Vehicle Risk in Rating Category No.6.

Rating Category No. 5: Roadway Impedance

Roadway Impedance	Shoulder Only	½ Roadway	¾ Roadway	Full Roadway

This category rates the impedance to traffic in the event of a failure of an unstable slope. It is based on the width of the roadway that is impacted.

Rating Category No. 6: Average Vehicle Risk (AVR)

Average Vehicle Risk	< 25% of the Time	25% to 50% of the Time	50% to 75% of the Time	> 100% of the Time

This category measures the percentage of time that a vehicle will be present in the unstable slope area. This AVR percentage is obtained by using the following formula:

$$AVR = \frac{\frac{\text{Average Daily Traffic}}{\text{24 Hours Per Day}} \times \text{Slope Length (miles)}}{\text{Posted Speed Limit (MPH)}} \times 100\%$$

A rating of 100% means that on average a vehicle will be present within the unstable area 100% of the time. The AVR number can be greater than 100%, where longer areas of instability exist in combination with high Average Daily Traffic. This means that there is more than one vehicle present within the unstable area at any given time.

Rating Category No. 7: Pavement Damage

Pavement Damage	Minor - Not Noticeable	Moderate - Driver Must Slow	Severe - Driver Must Stop	Extreme - Not Traversable

This category evaluates the severity of the potential damage to the roadway surface due to the failure of an unstable slope. The rating is based on the traversability of the unstable area by a motorist traveling at the posted speed limit. The degradation to the roadway surface must occur from the failure process, and not be due to normal wearing.

Rating Category No. 8: Failure Frequency

Failure Frequency	No Failures In The Last Five Years	One Failure In The Last Five Years	One Failure Each Year	More Than One Failure Per Year

This category prioritizes the failure frequency of the unstable slope. The information generated by the Maintenance Superintendents in Step No.1 of the unstable slope inventory process is used in this category.

Rating Category No. 9: Annual Maintenance Cost

Annual Maintenance Cost	< $5000 Per Year	$5000 to $10000 Per Year	$10000 to $50000 Per Year	> $50000 Per Year

This category measures the annual maintenance cost incurred for an unstable slope. The annual maintenance cost determined by the Maintenance Superintendents in Step No. 1 of the unstable slope inventory process is used in this category.

Rating Category No 10: Accidents in the Last 10 Years

This category rates the number of accidents that have occurred in the vicinity that may be associated with the unstable slope**.**

Rating Category No. 11: **Economic Factor**

Economic Factor	**No Detour Required**	**Short Detour < 3 Miles**	**Long Detour > 3 Miles**	**Sole Access No Detour Available**

This category rates the potential economic impact of a roadway closure as a result of a failure of an unstable slope. It is based on the availability and length of a detour around the failure area. When determining the suitability of a detour route several factors such as detour conditions, traffic volume, potential traffic flow, etc. must be evaluated. If a number of these factors could result in a major negative impact, even though a detour route is available, then a sole access rating should be given to the unstable slope.

Step No. 3: To develop rating consistency, the Geotechnical Branch Staff works in the field with the Regional Materials Engineers in rating and reviewing unstable slopes. Geotechnical Branch staff using GPS and a laser range finder can determine the specific location and dimensions of each unstable slope. Digital photos of the unstable slopes are maintained by the Geotechnical Branch and many can be viewed through the USMS intranet website.

Step No. 4: Within each highway functional class the slopes are ranked in descending numerical rating order, so the highest risk slopes within the functional class are considered first. After a ranked list of unstable slopes is developed, a first-cut list of slopes for the next biennium construction program is made based on anticipated funding level. A field review of these selected slopes is conducted to verify the numerical ratings and to describe the unstable slope problem in detail. A conceptual design for mitigation of the unstable slope is developed by the geotechnical staff with estimating factors. It is forwarded to the Regional Program Managers.

Step No. 5: The Regional Program Managers develop Project Definition cost estimates. They use the information from the conceptual mitigation recommendations and other required project items such as mobilization, traffic control, surfacing and paving, preliminary engineering, construction engineering, sales tax, and contingencies. Once these cost estimates are completed the Geotechnical Branch performs a cost-benefit analysis.

Step No. 6: The Geotechnical Branch conducts a cost-benefit analysis. A cost benefit for an unstable slope is determined by comparing the traffic delay cost and maintenance cost factored over the 20-year life of the program to the cost of mitigating the unstable slope. The two most reliable indicators of economic impact caused by a slope failure on a highway facility are the costs associated with traffic delays and the annual maintenance cost factored over the 20-year life of the program. Based on experience, in most cases traffic is disrupted for at least 24 hours after a slope failure. The life cycle maintenance cost is based on the estimated annual cost that has been generated by Regional Maintenance and multiplied by a 20-year program life. The maintenance cost and the traffic delay cost is compared with the cost of mitigation to determine the cost benefit ratio.

Step No. 7: Based on the analysis, unstable slopes are ranked by descending cost benefit ratio, forming a prioritized list of unstable slopes statewide for programming purposes. The unstable slope must have a cost benefit ratio greater than one to be on the prioritized list.

Step No. 8: The Office of Program Management, in concert with Executive Management, takes statewide deficiencies in all action strategies and makes decisions on where to commit funds based on available revenues. The funds are allocated to these action strategies based on performance outcomes and benefit. It should be noted that when a slope fails that is not on the priority list for the current biennium it is moved to the top of the priority list; emergency relief funding is sought, and state emergency bond money is used.